Energy management framework in a zero emissions port

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Outlines

• Introduction
• Ship’s Shore connection
• The concept of zero emissions port
• Energy demand from ships
• PSO (Particle Swarm Organization) algorithm
• Application to port’s grid energy management
• Conclusions
Introduction

• Cold ironing = connection of all ship’s electrical distribution systems with shore’s connection during ship’s port berthing.

• Traditionally during maintenance periods or in shipyards dry docking.

• New ship’s emission control in port rules requiring electrical energy from shore.
General arrangement
Practical problems

- Frequency
- Voltage (M/V on board)
- Safety during HV cables handling
- Several ship’s types - berthing procedures
Electrical connection 1/2
Electrical connection 2/2
Implementation in International Ports

- Göteborg, Lübeck, Zeebrügge, Ro/ro and/or
- Kotka, Kemi, Oulu Ferries
- Juneau, Seattle Cruise
- Antwerp Container
- Port of Los Angeles Container
- Port of Long Beach Container
- San Francisco, San Diego ...
Port of Los Angeles
Port of Long Beach
On-board Cable Connection
Wave energy
Pelamis & LIMPET
SMART GRID IN PORT

WINDTURBINES

WAVES

PV

GEOTHERMICS

CONTROL + DISTRIBUTION

H2

BATTERIES (NEW TYPE)

CONSUMPTION

TRANSPORTATION

Electrical company
ABB SVC Light with Energy Storage 5-50MW
Intelligent grid

• Available systems
  – Floating wind turbines
  – Photovoltaic systems
  – Wave energy
• New batteries
• Control systems
• Load’s control
• Grid’s stability
• RES penetration
• Energy saving

• Examples
  – Ydriada, Green island
### Summary of Power Demand

<table>
<thead>
<tr>
<th></th>
<th>Average Power Demand</th>
<th>Peak Power Demand</th>
<th>Peak Power Demand for 95% of the vessels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Container vessels (&lt; 140 m)</td>
<td>170 kW</td>
<td>1 000 kW</td>
<td>800 kW</td>
</tr>
<tr>
<td>Container vessels (&gt; 140 m)</td>
<td>1 200 kW</td>
<td>8 000 kW</td>
<td>5 000 kW</td>
</tr>
<tr>
<td>Container vessels (total)</td>
<td>800 kW</td>
<td>8 000 kW</td>
<td>4 000 kW</td>
</tr>
<tr>
<td>Ro/Ro- and Vehicle vessels</td>
<td>1 500 kW</td>
<td>2 000 kW</td>
<td>1 800 kW</td>
</tr>
<tr>
<td>Oil- and Product tankers</td>
<td>1 400 kW</td>
<td>2 700 kW</td>
<td>2 500 kW</td>
</tr>
<tr>
<td>Cruise ships (&lt; 200 m)</td>
<td>4 100 kW</td>
<td>7 300 kW</td>
<td>6 700 kW</td>
</tr>
<tr>
<td>Cruise ships (&gt; 200 m)</td>
<td>7 500 kW</td>
<td>11 000 kW</td>
<td>9 500 kW</td>
</tr>
<tr>
<td>Cruise ships (total)</td>
<td>5 800 kW</td>
<td>11 000 kW</td>
<td>7 300 kW</td>
</tr>
</tbody>
</table>
Cruise ship average power consumption – Port of Tallinn cruise ship demand
Introduction

- **Particle Swarm Optimization (PSO)**
  - Proposed by James Kennedy & Russell Eberhart in 1995
  - Inspired by social behavior of birds and fishes
  - Combines self-experience with social experience
Concept

- Uses a number of particles that constitute a swarm moving around in the search space looking for the best solution.

- Each particle in search space adjusts its “flying” according to its own flying experience as well as the flying experience of other particles.
Particle Swarm Optimization

- **Swarm**: a set of particles \( S \)
- **Particle**: a potential solution
  - Position: \( x_i = (x_{i,1}, x_{i,2}, \ldots, x_{i,n}) \in \mathbb{R}^n \)
  - Velocity: \( v_i = (v_{i,1}, v_{i,2}, \ldots, v_{i,n}) \in \mathbb{R}^n \)
- **Each particle maintains**
  - Individual best position (PBest)
- **Swarm maintains its global best (GBest)**

\[
S \xrightarrow{\text{Fitness function}} \text{Fitness value}
\]
PSO Algorithm

- Basic algorithm of PSO
  1. Initialize the swarm from the solution space
  2. Evaluate the fitness of each particle
  3. Update individual and global bests
  4. Update velocity and position of each particle
  5. Go to step 2, and repeat until termination condition
PSO flowchart

1. **start**
   - $k = 1$
   - Initialize $x_i(k), v_i(k)$
   - Compute $f(x_i(k))$

2. Reorder the particles
   - Generate neighborhoods
   - $i = 1$

3. Determine best particle in neighborhood of $i$

4. $i = i + 1$
   - Compute $x_i(k+1)$
   - Compute $f(x_i(k+1))$

5. Update previous best if necessary

6. $i \leq N_g$
   - yes
     - $i = i + 1$
     - $k = k + 1$
   - no

7. $k \leq K$
   - yes
     - stop
   - no

8. **stop**
Flowchart of proposed optimisation methodology

- Wind turbine Specs.
- PV Spec.
- Electrolyzer Specs.
- Hydrogen tank Specs.
- Fuel cell Specs.
- Heating/cooling systems demand after demand response
- Converter DC/AC Specs.
- Base Load
- Hourly wind speed and irradiance

Optimal sizing by PSO

Do the computed sizing satisfy the system constraints?

Selected the combination of components with lowest cost
Conclusions

• Gold ironing
• Smart grids for cold ironing
• RES at sea
• Smart RES management using PSO
• In future Smart meters, M2M, Smart Grid
Thank you for your attention

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